

This arrangement further decreases the electric field directed to the body member, such as finger.

[0076] For these reasons some embodiments of the invention aim at keeping the capacitance C1 low in comparison to that of C2. At least capacitance C1 should not be significantly higher than C2. Some embodiments aim at adjusting or controlling C2, for instance by coupling the reference potential of the apparatus back to the user, as will be shown in FIG. 12.

[0077] Instead of the measures described in connection with FIGS. 10 through 12, or in addition to such measures, stray capacitances can be controlled by arrangements in which several electrodes are used to generate potential differences among different areas of the touch screen surface. By way of example, this technique can be implemented by arranging the touch-sensitive surface of a hand-held device (eg the top side of the device) to a first potential, while the opposite side is arranged to a second potential, wherein the two different potentials can be the positive and negative poles of the device. Alternatively, a first surface area can be the electric ground (reference potential), while a second surface area is charged to a high potential.

[0078] Moreover, within the constraints imposed by the insulator layer(s), it is possible to form minuscule areas of different potentials, such as potentials with opposite signs or widely different magnitudes, wherein the areas are small enough that the user's body member, such as finger, is simultaneously subjected to the electric fields from several areas with different potentials.

[0079] FIG. 13 shows an embodiment in which the capacitive coupling is utilized to detect touching or approaching by the user's body member, such as finger. A detected touching or approaching by the user's body member can be passed as an input to a data processing equipment. In the embodiment shown in FIG. 13, the voltage source is floating. A floating voltage source can be implemented, via inductive or capacitive coupling and/or with break-before-make switches. A secondary winding of a transformer is an example of a simple yet effective floating voltage source. By measuring the voltage U4, it is possible to detect a change in the value(s) of capacitance(s) C1 and/or C2. Assuming that the floating voltage source is a secondary winding of a transformer, the change in capacitance(s) can be detected on the primary side as well, for example as a change in load impedance. Such a change in capacitance(s) serves as an indication of a touching or approaching body member.

[0080] In one implementation, the apparatus is arranged to utilize such indication of the touching or approaching body member such that the apparatus uses a first (lower) voltage to detect the touching or approaching by the body member and a second (higher) voltage to provide feedback to the user. For instance, such feedback can indicate any of the following: the outline of the/each touch-sensitive area, a detection of the touching or approaching body member by the apparatus, the significance of (the act to be initiated by) the touch-sensitive area, or any other information processed by the application program and which is potentially useful to the user.

[0081] FIG. 14 schematically illustrates an embodiment in which a single electrode and temporal variations in the intensity of the electro-sensory stimulus can be used to create illusions of a textured touch screen surface. Reference numeral 1400 denotes a touch-sensitive screen which, for the purposes of describing the present embodiment, comprises three touch-sensitive areas A₁, A₂ and A₃. The approaching or

touching by the touch-sensitive areas A₁, A₂ and A₃ of a user's finger 120 is detected by a controller 1406.

[0082] According to an embodiment of the invention, a conventional touch-sensitive screen 1400 can be complemented by a tactile output device according to an embodiment of the invention. Reference numeral 1404 denotes an electrode which is an implementation of the electrodes described in connection with previously-described embodiments, such as the electrode 106 described in connection with FIGS. 1 and 2. A supplemental insulator 1402 may be positioned between the touch-sensitive screen 1400 and the inventive electrode 1404, in case the touch-sensitive screen 1400 itself provides sufficient insulation.

[0083] In addition to conventional touch-screen functionality, namely detection of approaching or touching by the touch-sensitive areas by the user's finger, the controller 1406 uses information of the position of the finger 120 to temporally vary the intensity of the electro-sensory stimulation invoked by the electrode 1404 on the finger 120. Although the intensity of the electro-sensory stimulation is varied over time, time is not an independent variable in the present embodiment. Instead, timing of the temporal variations is a function of the position of the finger 120 relative to the touch-sensitive areas (here: A₁, A₂ and A₃). Thus it is more accurate to say that the present embodiment is operable to cause variations in the intensity of the electro-sensory stimulation invoked by the electrode 1404 on the finger 120, wherein the variations are based on the position of the finger 120 relative to the touch-sensitive areas.

[0084] The bottom side of FIG. 14 illustrates this functionality. The three touch-sensitive area A₁, A₂ and A₃ are demarcated by respective x coordinate pairs {x₁, x₂}, {x₃, x₄} and {x₅, x₇}. (Processing in the y direction is analogous and a detailed description is omitted.) The controller 1406 does not sense the presence of the finger, or senses the finger as inactive, as long as the finger is to the left of any of the touch-sensitive areas A₁, A₂ and A₃. In this example the controller 1406 responds by applying a low-intensity signal to the electrode 1404. As soon as the finger 120 crosses the x coordinate value x₁, the controller 1406 detects the finger over the first touch-sensitive area A₁ and starts to apply a medium-intensity signal to the electrode 1404. Between the areas A₁ and A₂ (between x coordinates x₂ and x₃), the controller again applies a low-intensity signal to the electrode 1404. The second touch-sensitive area A₂ is processed similarly to the first touch-sensitive area A₁, but the third touch-sensitive area A₃ is processed somewhat differently. As soon as the controller 1406 detects the finger 120 above or in close proximity to the area A₃, it begins to apply the medium-intensity signal to the electrode 1404, similarly to areas A₁ and A₂. But the user decides to press the touch screen 1400 at a point x₆ within the third area A₃. The controller 1406 detects the finger press (activation of the function assigned to the area A₃) and responds by applying a high-intensity signal to the electrode 1404.

[0085] Thus the embodiment shown in FIG. 14 can provide the user with a tactile feedback which creates an illusion of a textured surface, although only a single electrode 1404 was used to create the electro-sensory stimulus. A residual problem is, however, that the user has to memorize the significance of the several touch-sensitive areas or obtain visual or aural information on their significance.

[0086] FIG. 15 shows a further enhanced embodiment from the one described in connection with FIG. 14. The embodi-